Dynamic chiral selection and amplification using photoresponsive organogelators

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Starting materials were commercially available and were used without further purification. Melting points were determined on a Büchi melting point apparatus and are uncorrected. ^{1}H NMR were recorded on a Varian VXR-300 spectrometer (at 300 MHz) or a Varian 500 spectrometer (at 500 MHz) at ambient temperature. The splitting patterns are designated as follows: s (singlet); d (doublet); dd (double doublet); t (triplet); q (quartet); m (multiplet) and br (broad). ^{13}C NMR were recorded on a varian VXR-300 (at 75.4 MHz). Chemical shifts are denoted in δ (ppm) referenced to the residual protic solvent peaks. Coupling constants *J*, are denoted in Hz. Masses were recorded with a MS-Jeol mass spectrometer, with ionisation according to CI^{+}, DEI or EI^{+} procedures by A. Kiewiet. Aldrich silica gel Merck grade 9385 (230-400 mesh) was used for column chromatography. The solvents were distilled and dried before use, if necessary, using standard methods. Reagents and starting materials were used as obtained from Aldrich, Acros Chimica or Fluka. Derivates synthesized are light sensitive and were therefore exclusively handled in the dark using brown glassware, and column chromatography was performed in yellow light. Irradiations were performed with a high pressure mercury lamp (200W, Oriel) and the appropriate filters (Andover corporation). CD spectra were recorded on a JASCO J-715 spectropolarimeter and UV measurements were performed on a Hewlett-Packard HP 8453 FT Spectrophotometer. Synthesis was done according to literature procedures.[1]

LMWGs are known to be very dependent on cooling rate, concentration, and are easily disturbed by mechanical stress. For instance, rapid quenching in liquid N_2 of the hot solutions leads to loss of asymmetric induction. As controle experiments, we used mixtures of **3o** and **1o** at concentrations between 0.5 and 5 mM at 1:1 and 2:1 ratios still gave over 90% e.e. for **3c**, but at higher concentrations (> 5 mM) the e.e. drops (74% e.e.), presumably because the aggregates form to quickly at these high concentrations. Prolonged aging times lead again to slightly higher e.e. values (increase up to 10%). Similar results were obtained for *c*-hexane and decalin as solvent. The use of the (S)-enantiomer of **1o** results in opposite CD spectra and the formation of the other enantiomer of **3c** with similar high e.e. (determined by HPLC), whereas the use of **1o** with racemic ethyl phenyl amine auxiliary groups mixed with **3o** gives no induction.

The estimated soldiers/sergeant ratio of 8 is only valid under the assumptions that the ratio of soldier and sergeant in the gel and in solution are the same. Obviously, these levels of amplification can only be observed if the soldier to sergeant ratio is equal to or larger than this value. Indeed, going to lower soldier to sergeant ratios leads to higher e.e.'s but lower levels of amplification. On the other hand, at a soldier to sergeant ratio of **3o**/**1o**=40 with an e.e. of 25% one can calculate that even 10 soldiers are influenced by 1 sergeant. However, because of the larger error in the e.e, the more conservative value of 8 at a ratio of **3o**/**1o**=20 is reported. A deviation of the co-assembled ratio from the given ratio of **3o**/**1o** will lead to lower numbers then 8 soldiers influenced by 1 sergeant. Preferential incorporation of sergeant up to a level of 1 sergeant to 8 soldiers instead of the given ratio of **3o**/**1o**=20 could explain why 1 sergeant influences only 8 soldiers. If even more sergeant is incorporated this would lead to lower numbers of amplification, which is not in line with the observed e.e of 40% at a 20/1 ratio. On the other hand, if less sergeant then the given ratio is incorporated in the assemblies the actual level of amplification would even be higher.

1,2-Bis(2'-methyl-5'-{[((R)-1-phenylethyl)amino]carbonyl} thien-3'-yl)cyclopentene (1): This compound was prepared as described for literature,[1] starting from 1,2-Bis(2'-methyl-5'-carbonyl}thien-3'-yl) cyclopentene (A) (0.50 g, 1.44 mmol) and (R)-phenylethylamine (0.37 ml, 2.9 mmol). After purification, column chromatography (solid silica, CH_2Cl_2 : MeOH (60:1)) and stirring $ether_{(excess)}$ / MeOH, an off-white solid was obtained (0.28 g, 35%), mp. 207°C decomp.; ^{1}H NMR (300MHz, $CDCl_3$) δ_H 1.55 (d, *J* = 6.9 Hz, 6H), 1.90 (s, 6H), 1.97-2.07 (m, 2H), 2.74 (t, *J* = 7.4 Hz, 4H), 5.19-5.29 (m, 2H), 7.18 (s, 2H), 7.26-7.38 (m, 10H); ^{13}C NMR (75.4 MHz, $CDCl_3$) δ_C 14.7 (q), 21.7 (q), 22.8 (t), 38.5 (t), 49.1 (t), 126.3 (d), 127.5 (d), 128.7 (d), 129.4 (d), 134.2 (s), 134.7 (s), 136.3 (s), 139.9 (s), 143.0 (s), 160.8 (s); MS (EI): 554 [M^{+}] HRMS calcd. for $C_{33}H_{34}N_2O_2S_2$ 554.206, found 554.205.

1,2-Bis(2'-methyl-5'-{[((R)-1-cyclohexylethyl)amino] carbonyl}thien-3'-yl)cyclopentene (2): This compound was prepared as described for literature,[1] starting from (A) (1.34 g, 3.85 mmol) and (R)-cyclohexylamine (1.1 ml, 7.7 mmol). After purification, column chromatography (solid silica, CH_2Cl_2 : MeOH (60:1)) and stirring $ether_{(excess)}$ / MeOH, an off-white solid was obtained (0.59g, 44%), mp. 209°C decomp.; ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 0.93 (d, *J* = 5.6, 2H), 1.15-1.46 (m, 8H), 1.22 (d, *J* = 4.4, 6H), 1.62-1.77 (m, 12H), 1.94 (s, 6H), 2.00-2.10 (m, 2H), 2.78 (t, *J* = 7.2 Hz, 4H), 3.93-4.02 (m, 2H), 5.52 (d, *J* = 9.0 Hz, 2H), 7.17 (s, 2H); ^{13}C-NMR (74.5 MHz, $CDCl_3$) δ_C 14.7 (q), 17.9 (q),

22.9 (t), 26.2 (t), 26.4 (t), 29.1 (t), 38.4 (t), 43.2 (d), 49.8 (d), 129.1 (d), 134.6 (s), 134.8 (s), 136.3 (s), 139.4 (s), 161.0 (s); MS (EI): 566 [M^+]; HRMS calcd. for $C_{33}H_{46}N_2O_2S_2$ 566.300, found 566.299.

1,2-Bis(5'-[(cyclohexylamino)carbonyl]-2'-methyl-thien-3'-yl)cyclopentene (3): This compound was prepared as described for literature,[1] starting from (A) (0.500 g, 1.44 mmol) and cyclohexylamine (0.31 ml, 2.9 mmol). After purification, column chromatography (solid silica, CH_2Cl_2 : MeOH (60:1)) and stirring $ether_{(excess)}$ / MeOH, an off-white solid was obtained (0.068 g, 0.13 mmol, 9%), mp. 256-260°C decomp.; ^{1}H NMR (500MHz, $CDCl_3$) δ_H 1.14-1.23 (m, 8H), 1.34-1.43 (m, 4H), 1.61 (q, *J* = 4.3 Hz, 4H), 1.63-1.69 (m, 4H), 1.91 (s, 6H), 1.96 (d, 4H) 2.05 (m, 2H), 2.76 (t, *J* = 7.5, 4H), 3.83-3.90 (m, 2H), 5.55 (d, *J* = 7.5, 2H), 7.15 (s, 2H); ^{13}C NMR (75.4 MHz, DMSO): δ_C 14.2 (q), 22.3 (t), 24.9 (t), 25.2 (t), 32.5 (t), 38.3 (d), 48.2 (t), 128.6 (d), 134.0 (s), 136.0 (s), 138.5 (s), 146.2 (s), 159.9 (s); MS (EI): 510 [M^+]; HRMS calcd. for $C_{29}H_{38}N_2O_2S_4$ 510.237, found 510.237.

1 Lucas, L.N.; de Jong, J.J.D.; van Esch, J.H.; Kellogg, R.M.; Feringa, B.L., *Eur. J. Org. Chem*. **2003**, 155-166.